An exploratory study on coronary sinus lead tip three-dimensional trajectory changes in cardiac resynchronization therapy

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BACKGROUND Prediction of response to cardiac resynchronization therapy (CRT) is still an unsolved major issue. The interface between left ventricular mechanics, coronary sinus (CS) lead, and pacing delivery has been little investigated.

OBJECTIVE To investigate CS lead tip movements at baseline and during biventricular pacing (BiV) in the hypothesis that they could provide some insights into left ventricular mechanical behavior in CRT.

METHODS Three-dimensional reconstruction of CS lead tip trajectory throughout the cardiac cycle using a novel fluoroscopy-based method was performed in 22 patients with chronic heart failure (19 men; mean age 70 ± 10 years). Three trajectories were computed: before (T_{-1}) and immediately after (T_0) BiV start-up and after 6 months (T_1). CRT response was the echocardiographic end-systolic volume reduction ≥15% at T_1. Metrics describing trajectory at T_0, T_{-1}, and T_1 were compared between 9 responders (R) and 13 nonresponders (NR).

RESULTS At T_{-1} trajectories demonstrated heterogeneous shapes and metrics, but at T_0 the variations in the ratio between the two main axes (S_1/S_2) and in the eccentricity were statistically different between R and NR, pointing out a trajectory's change toward a significantly more circular shape at BiV start-up in R. Remarkably, R and NR could be completely separated by means of the percent variation in S_1/S_2 from T_{-1} to T_0 (R: 47.5% [31.5% to 54.1%] vs NR: −25.6% [−67% to −6.5%]). This single marker computed at T_0 would have predicted CRT response at T_1.

CONCLUSIONS Preliminary data showed that CS lead tip trajectory changes induced by BiV were related to mechanical resynchronization.

KEYWORDS Cardiac resynchronization therapy; Left ventricular reverse remodeling; Left ventricular pacing; Left ventricular mechanics; Heart failure

ABBREVIATIONS **3D** = three-dimensional; **BiV** = biventricular pacing; **CRT** = cardiac resynchronization therapy; **CS** = coronary sinus; **EDV** = end-diastolic volume; **EF** = ejection fraction; **ESV** = end-systolic volume; **LBBB** = left bundle branch block; **LV** = left ventricle/ventricular; **LVRER** = left ventricular reverse remodeling; **NR** = nonresponders; **NYHA** = New York Heart Association; **QRS** = QRS complex duration; **R** = responders; **RV** = right ventricular; $\mathbf{T_{-1}}$ = timing of data acquisition before biventricular pacing start-up; $\mathbf{T_0}$ = timing of data acquisition immediately after biventricular pacing start-up; $\mathbf{T_1}$ = timing of data acquisition at 6-month follow-up; **VMD** = ventricular mechanical dyssynchrony

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Introduction

Among several unsolved issues in cardiac resynchronization therapy (CRT), the prediction of left ventricular (LV) mechanical response to biventricular pacing (BiV) is foremost.[1,2] Multiple factors play a role in resynchronization, such as myocardial structure and conduction, arrhythmias, dyssynchrony, lead placement, uninterrupted BiV, and comorbidities.[1] The keystone to CRT benefits seems to be the correction or the abolishment of ventricular mechanical dyssynchrony (VMD), which in turn promotes LV reverse remodeling (LVRER).[3–5] The continuous interaction between the electrode in coronary sinus (CS) branches and the myocardium remains crucial since it determines the effects of BiV. Evidence has long been scarce about lead dynamics inside CS, although it could both describe the interface where treatment is applied and render some information about underlying myocardial mechanics. The recently published method by our groups has supplied a tool to investigate the movements of the electrode distal tip inside CS branch during cardiac cycles by reconstructing in three-dimensional (3D) space the instantaneous lead tip's geometric trajectory.[6] The first aim of the present exploratory work has been to evaluate the acute effects of BiV at implant on CS lead tip 3D movements throughout cardiac cycles. Second, we sought to investigate the correlations between the time-course variations in tip's geometric trajectory and the mid-term echocardiographic LVRER.

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Methods

Population

Twenty-two patients with chronic heart failure (Caucasian; 19 men; mean age 70 $\pm$10 years) submitted to the implantation of a CRT device in a single center with a current class I or IIA indication[2] were enrolled. CRT devices had defibrillator capabilities in 14 cases, and 8 were pacemakers. Upgrades were 9, of whom 7 needed a constant ventricular pace because of a slow spontaneous ventricular rate. Left bundle branch block (LBBB) morphology was typical in 8 cases, nontypical in 7, and right ventricular (RV) pacing-induced in 7.

Enrollment criteria were as follows: chronic heart failure recognized for more than 6 months; no paroxysmal/persistent sustained supraventricular tachyarrhythmia in the previous 12 months; no myocardial infarction, coronary revascularization, and cardiac surgery in the past 6 months; in upgrades, previous implants had to be older than 6 months; no bradyarrhythmia needing de novo permanent pacing; at implant, stable clinical and hemodynamic conditions with a regular, normofrequent ventricular rhythm, either spontaneous or paced; sinus rhythm or atrial fibrillation with permanent high-degree AV block and constant ventricular pace due to a spontaneous rate $<$45 beats/min.

At X-ray acquisitions, patients had to be asymptomatic, with stable blood pressure, heart and respiratory rate—the last not exceeding 25 breaths/min.

Baseline patient characteristics are listed in Table 1.

Data were acquired before and immediately after BiV start-up (T_{-1} and T_0), and at 6-month follow-up (T_1).

The protocol was approved by the Area Vasta Romagna Ethics Committee, and patients gave informed consent.

CRT implantation and follow-up

Implantation was carried out transvenously under local anesthesia. LV lead was positioned with an over-the-wire technique preferably in a postero- to anterolateral CS vein at a nonapical level, avoiding echocardiographic scar areas. Right atrial and ventricular leads were placed conventionally. All market-released CRT devices could be implanted. During the procedure, de novo implants were programmed in the ODO mode and upgrades were kept with the preexisting programming. T_{-1} radiological recording was acquired just after procedure completion, immediately followed by the start-up of simultaneous BiV with an atrioventricular delay of 120 ms and by T_0 radiological acquisition. Before discharge, the optimization of atrioventricular and interventricular intervals was performed using aortic velocity-time integral by Doppler echocardiography and settings were left unmodified up to T_1. LV autocapture was used, if available; otherwise, LV output was programmed at least twice the maximum threshold. Clinical, echocardiographic, and device assessments were performed every 2 months. Percentage of BiV pacing and burden of tachyarrhythmias were collected at each follow-up.

Echocardiographic assessment

Echocardiography was performed before CRT implant and at T_1 by an experienced physician blinded to both clinical and

Table 1 Baseline clinical features of the study population and comparison between responders (R) and nonresponders (NR)

	All (n = 22, 100%)	R (n = 9, 41%)	NR (n = 13, 59%)
Age (y)	70.9 ± 10.6	73.2 ± 6.4	69.3 ± 12.7
Sex: male	20 (90%)	9 (100%)	11 (84%)
Heart rate (beats/min)	74 ± 11	71 ± 8	76 ± 13
Upgrade	9 (40%)	5 (55%)	4 (30%)
Ischemic heart disease	8 (37%)	3 (33%)	5 (39%)
Hypertension	11 (50%)	3 (33%)	8 (61%)
Diabetes	9 (41%)	2 (22%)	7 (54%)
Valvular prosthesis/previous coronary surgery	0	0	0
Previous percutaneous coronary angioplasty	7 (32%)	2 (22%)	5 (39%)
QRS (ms)	172 ± 22	170 ± 25	173 ± 21
Left bundle branch block			
Typical	8 (36%)	3 (33%)	5 (38%)
Nontypical	7 (28%	3 (33%)	4 (31%)
RV pace induced	7 (36%)	3 (33%)	4 (31%)
Permanent atrial fibrillation	2 (9%)	1 (11%)	1 (7%)
Serum creatinine ≥1.8 mg/dL	6 (27%)	0 (0%)*	6 (46%)*
Mitral regurgitation ≥ moderate	6 (27%)	1 (11%)	5 (39%)
EDV (mL)	259 ± 74	255 ± 48	262 ± 89
ESV (mL)	181 ± 59	177 ± 38	184 ± 71
EF (%)	29 ± 5	28 ± 5	29 ± 5
Lateral placement of CS lead	18 (82%)	9 (100%)	9 (69%)
Fluoroscopy total time (min)	31 ± 11	33 ± 13	30 ± 9

Values are expressed as n (%) or as mean ± SD.

CS = coronary sinus; EDV = end-diastolic volume; EF = ejection fraction; ESV = end-systolic volume; QRS = QRS duration on surface electrocardiogram; RV = right ventricular.

*P = .046.